Seismic Response Study of Tall Building with Combined Irregularities

MD ANWAR ULLAH ANSARI (1), MR IMTIYAZ QURESHI(2)
[1]*M.Tech Student, Department of Civil Engineering,*
[2]*Guide, Assistant Professor, Department of Civil Engineering,*
Nawab Shah Alam Khan College of Engineering and Technology

***Abstract*—The combined irregularities considered in this research encompass vertical mass irregularities, stiffness irregularities, and torsional irregularities, which are often encountered in real-world structures. The present work aims to demonstrate the effect of an outrigger system for regular and vertical irregular high-rise structures considering mass, stiffness, and geometric irregularity for outriggers and belt trusses with X and V topology placed at different stories. The building studied in this section is a 40-story Reinforced Concrete Special Moment Resisting Space frame designed for Gravity and Seismic Loads Using non-linear dynamic Analysis. The structure is evaluated in accordance with seismic code IS-1893:2016 using Non-linear time history analysis with the help of the ETABS version 2021 software (CSI Ltd) analysis engine**

***Keywords*—Dynamic analysis, non-linear time history analysis, outriggers, and belt trusses with X and V topology, regular and vertical irregularity.**

I. INTRODUCTION

Earthquakes, as natural disasters, pose a significant risk to urban structures, making it imperative to comprehend how different irregularities in a building's design and construction might influence its performance during seismic events. Irregularities, such as vertical setbacks, mass irregularities, and soft-story configurations, can significantly amplify seismic forces and lead to disproportionate levels of damage. The interaction of these irregularities, when combined in a single structure, adds an additional layer of complexity to the seismic response. The importance of studying buildings with combined irregularities lies in their representation of real-world scenarios. Urban landscapes often feature structures with a myriad of irregularities, introduced either by architectural necessities or constraints in construction. These irregularities can compromise the overall structural integrity and exacerbate the vulnerability of a building when subjected to seismic forces. Understanding how these irregularities interact synergistically is crucial for developing effective seismic design strategies and retrofitting measures. To study combined irregularity present in a buildings structure and evaluate seismic response using the Non-linear time history analysis

- To study different types irregularities as mass, geometric and stiffness and their effect with outrigger.
- To determine the best location of possible outriggers (10 story, 20 story and 40th story) Arrangement by comparison of results for seismic action.
- To assess the performance of structure in terms of story displacement, story drift, story stiffness and time period.

II. LITERATURE REVIEW

Felipe Morrone Barbat Parfit (2023) (1): This paper aims to investigate a methodology for determining the optimum floor positioning of outriggers (ORs) and belt-trusses (BTs) over tall buildings height. The primary goal is to reduce the maximum lateral drift (MLD) and the core base moment (CBM), individually and concurrently. Furthermore, the influence of these elements on other criteria such as maximum acceleration and natural frequencies are analyzed. Throughout the work, the behavior of the structure is verified when the stiffness ratio of the main elements used in the bracing system (core, perimeter columns, OR, and BT) are varied. Therefore, a three-dimensional model of a tall building under lateral wind load is analyzed, using the finite element method with ANSYS software.
Gholamreza Abdollahzadeh, Hadi Faghihmaleki and Reza Alghosi (2022) (2): The outrigger arm system and belt truss with braced core in the center of the structure surrounded by belts truss, is an efficient and reliable system for high -rise buildings against severe lateral forces such as earthquake and wind. The purpose of this research is investigating the outrigger

arm system and belt truss with the braced core under lateral loads. Another purpose of this research is to reduce the drift and displacement of the roof against these loads with deformation and finding the optimal location for the outrigger arm through various methods. Analysis of nonlinear time history and spectral analysis of the site with a high relative risk for the three models of 30, 45, and 60 floors have shown that the optimum location of the outrigger arm and belt truss with the proposed method in this research has been better more noteworthy than the previous methods and caused decreasing as it has induced about a decrease in absolute roof displacement and maximum relative displacement of floors..

Alaa Habrah, Mustafa Batikha (2022) [3]: The location and number of outriggers in a core-outrigger lateral resisting system have a major influence on the tall buildings' performance and the design's cost efficiency. In this study, an analytical procedure was performed to produce a general equation of the top lateral displacement of a core-outrigger system (up to four outriggers) due to various static lateral loading distribution forms (uniform, triangular and parabolic). Moreover, the optimal positions of outriggers that produce the maximum top displacement reduction are determined in this research. On the other hand, this work proposes the maximum height of a tall building corresponding to displacement limit criteria, number of the outrigger and outrigger positions.

1. Module And Building Configuration

VERTICAL IRREGULAR MODEL

Geometric irregularity

Model 1: First building is modelled with Vertical geometric irregularity with beams, Columns, Shear Core walls, and Slabs. The lateral load resisting structural system is adopted by studying IS 1893 2016 and labelled as irregular model without outrigger and belt truss.

Model 2: Second building with Vertical geometric irregularity is modelled with lateral load resisting structural system with outrigger and belt truss with x topology

- Outrigger and belt truss at 10th story
- Outrigger and belt truss at 20th story
- Outrigger and belt truss at 40th story

Model 3: Second building with Vertical geometric irregularity is modelled with lateral load resisting structural system with outrigger and belt truss with V topology

- Outrigger and belt truss at 10th story
- Outrigger and belt truss at 20th story
- Outrigger and belt truss at 40th story

Geometric + mass irregularity

Model 4: The building is modelled with Vertical geometric and mass irregularity with beams, Columns, Shear Core walls, and Slabs. The lateral load resisting structural system is adopted by studying IS 1893 2016 and labelled as irregular model without outrigger and belt truss.

Model 5: The building with Vertical geometric and mass irregularity is modelled with lateral load resisting structural system with outrigger and belt truss with x topology

- Outrigger and belt truss at 10th story
- Outrigger and belt truss at 20th story
- Outrigger and belt truss at 40th story

Model 6: The building with Vertical geometric and mass irregularity is modelled with lateral load resisting structural system with outrigger and belt truss with V topology

- Outrigger and belt truss at 10th story
- Outrigger and belt truss at 20th story
- Outrigger and belt truss at 40th story

Geometric + stiffness irregularity

Model 7: The building is modelled with Vertical geometric and stiffness irregularity with beams, Columns, Shear Core walls, and Slabs. The lateral load resisting structural system is adopted by studying IS 1893 2016 and labelled as irregular model without outrigger and belt truss.

Model 8: The building with Vertical geometric and stiffness irregularity is modelled with lateral load resisting structural system with outrigger and belt truss with x topology

- Outrigger and belt truss at 10th story
- Outrigger and belt truss at 20th story
- Outrigger and belt truss at 40th story

Model 9: The building with Vertical geometric and stiffness irregularity is modelled with lateral load resisting structural system with outrigger and belt truss with V topology

- Outrigger and belt truss at 10th story
- Outrigger and belt truss at 20th story

Outrigger and belt truss at 40th story

Geometric + stiffness + mass irregularity

Model 10: The building is modelled with Vertical geometric, mass and stiffness irregularity with beams, Columns, Shear Core walls, and Slabs. The lateral load resisting structural system is adopted by studying IS 1893 2016 and labelled as irregular model without outrigger and belt truss.

Model 11: The building with Vertical geometric mass and stiffness irregularity is modelled with lateral load resisting structural system with outrigger and belt truss with x topology

- Outrigger and belt truss at 10th story
- Outrigger and belt truss at 20th story
- Outrigger and belt truss at 40th story

Model 12: The building with Vertical geometric mass and stiffness irregularity is modelled with lateral load resisting structural system with outrigger and belt truss with V topology

- Outrigger and belt truss at 10th story
- Outrigger and belt truss at 20th story
- Outrigger and belt truss at 40th story

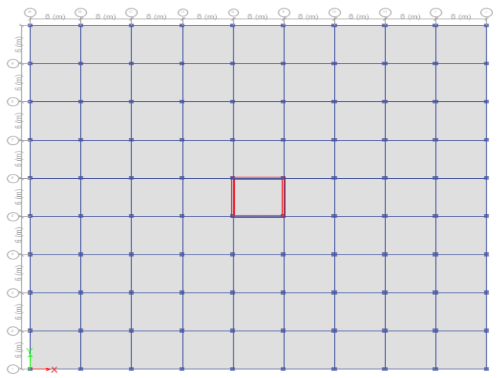

Figure 1: Plan view of G+40 storey building

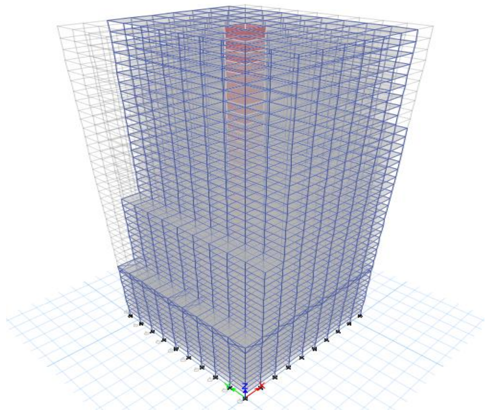

Figure 2: Isometric view of G+40 building with vertical irregularity

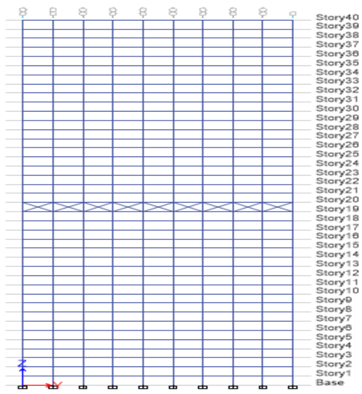

Figure 3: Isometric view of G+40 building with x-outrigger topology

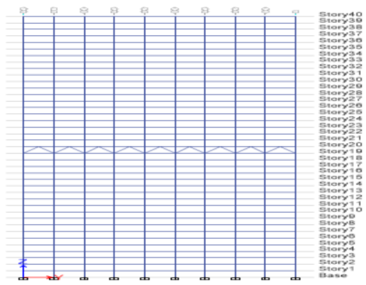

Figure 4: Isometric view of G+40 building with v-outrigger topology

III. RESULTS FOR MODELS

STORY DISPLACEMENT FOR REGULAR MODEL

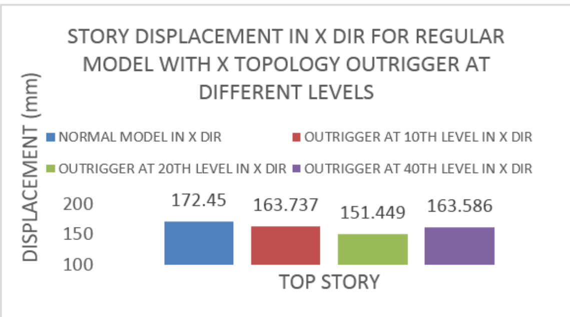

Figure 5: story displacement in the X dir (X topology)

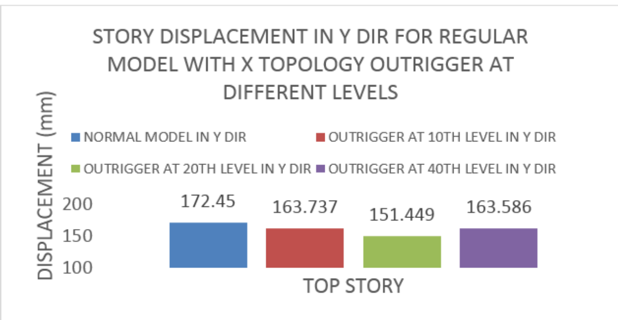

Figure 6: story displacement in Y dir(X topology)

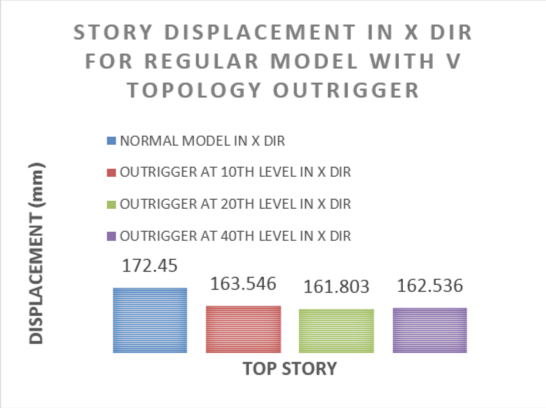

Figure 7: story displacement in the X dir (v topology)

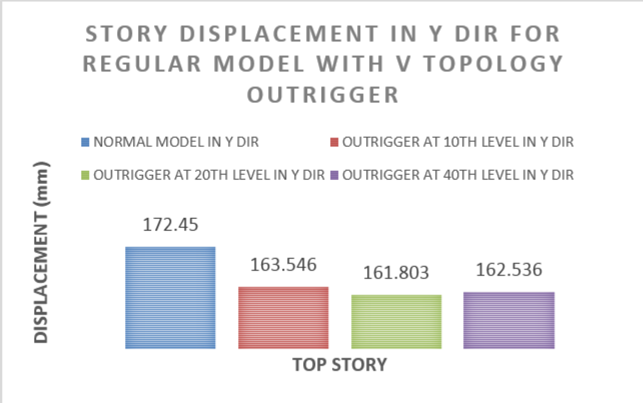

Figure 8: story displacement in Y dir (v topology)

STORY DISPLACEMENT FOR IRREGULAR MODEL FOR GEOMETRIC IRREGULARITIES

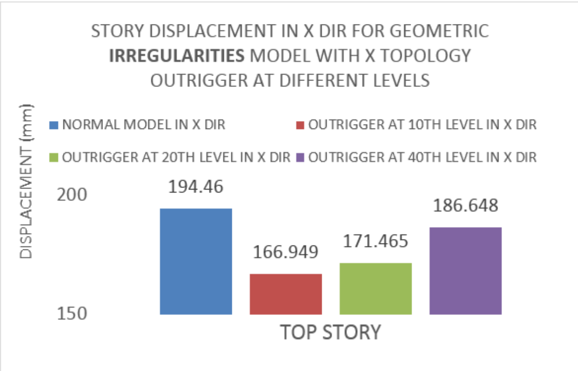

Figure 9: story displacement in the X dir (X topology)

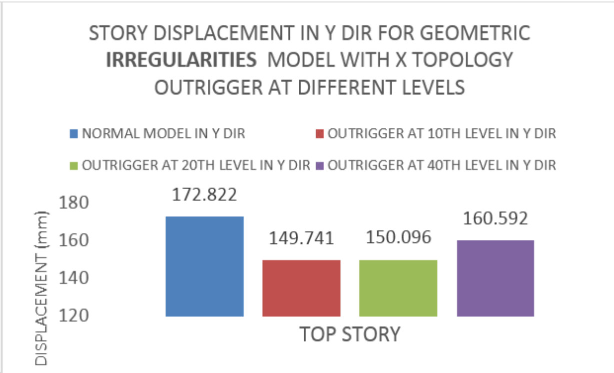

Figure 10: story displacement in Y dir(X topology)

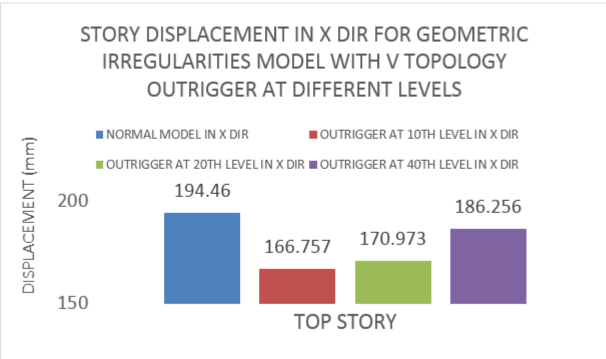

Figure 11: story displacement in the X dir (v topology)

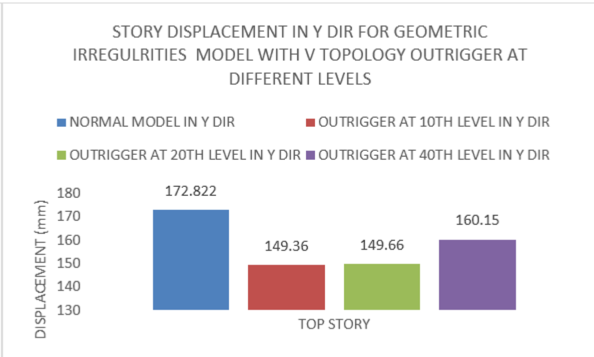

Figure 12: story displacement in Y dir (v topology)

STORY DISPLACEMENT FOR IRREGULAR MODEL FOR GEOMETRIC AND MASS IRREGULARITY

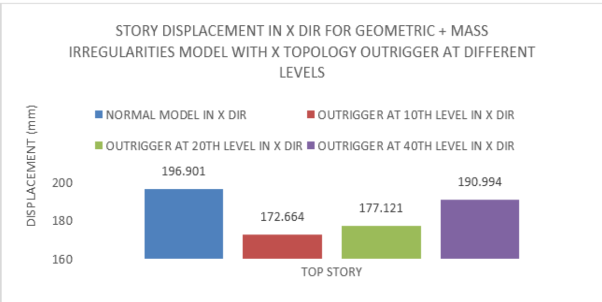

Figure 13: story displacement in the X dir (X topology)

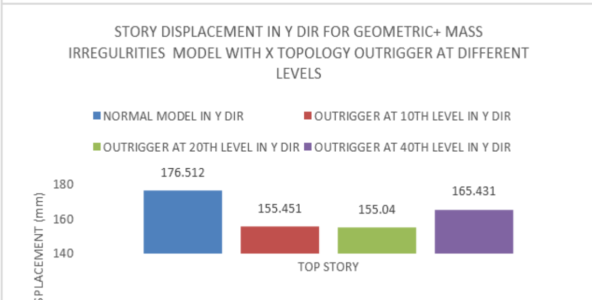

Figure 14: story displacement in Y dir(X topology)

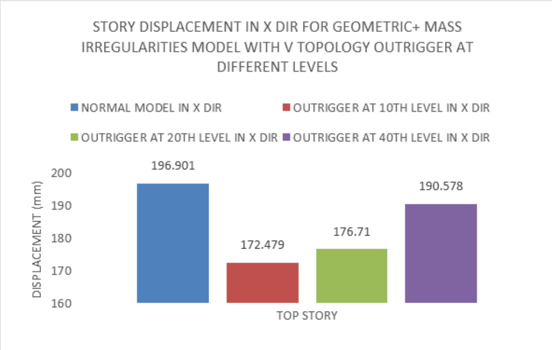

Figure 15: story displacement in the X dir (v topology)

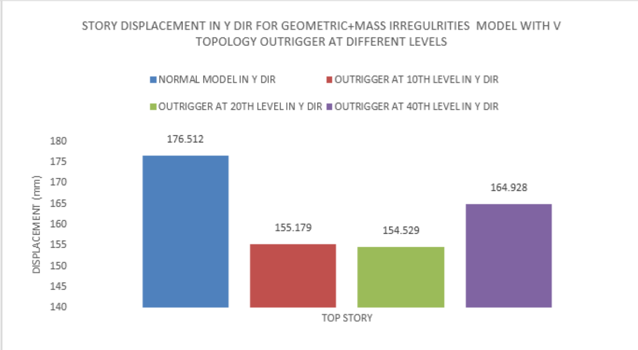

Figure 16: story displacement in Y dir (v topology)

STORY DISPLACEMENT FOR IRREGULAR MODEL FOR GEOMETRIC AND STIFFNESS IRREGULARITY

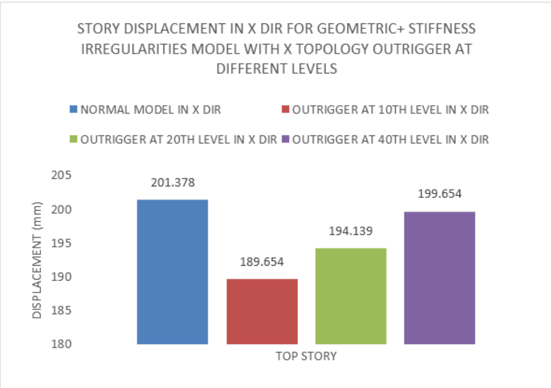

Figure 17: story displacement in the X dir (X topology)

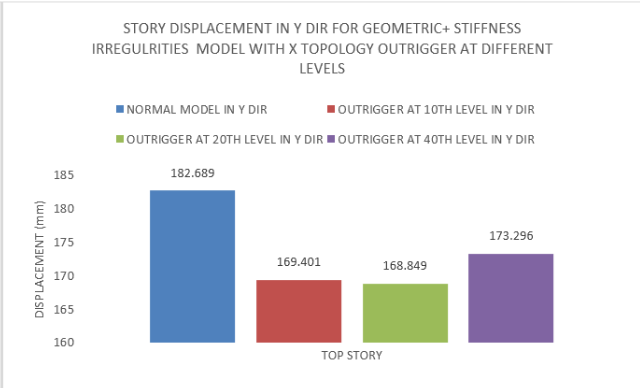

Figure 18: story displacement in Y dir(X topology)

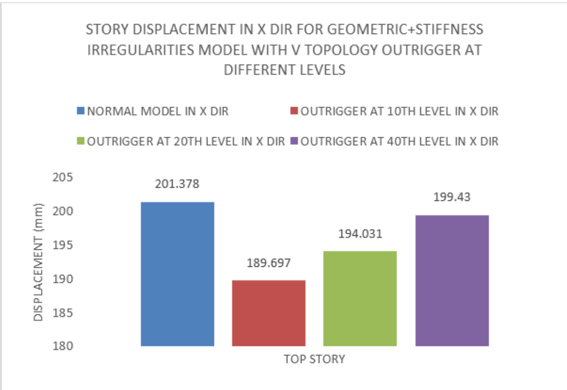

Figure 19: story displacement in the X dir (v topology)

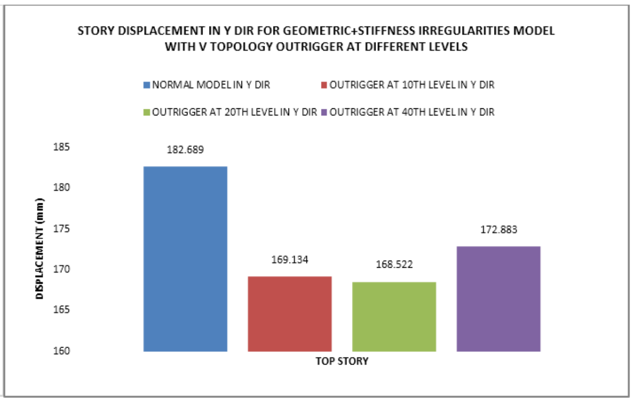

Figure 20: story displacement in Y dir (v topology)

IV. CONCLUSION

- This dissertation investigates the comparison of the high rise buildings with considering 40 Storey buildings with different outrigger topology as X and V type, all the buildings are with floor size 54mX54m and typical Storey height as 3m, the first structural system i.e. RCC moment resisting frame, in these system the elements or the structural members are designed for gravity and lateral loads. The use of outrigger system in high-rise buildings increases the stiffness and makes the structural form efficient under lateral load. When outrigger is at 10^{th} and 40^{th} the displacement with x topology is reduced by 5.23% and 5.47%, whereas with v topology is 5.45% and 5.81%.
- For regular model with outrigger at 20 story has better results compared to outrigger at different level, as the displacement is reduced by 12.2% with x topology outrigger, and 7.15% with v topology outrigger.

- The percentage of reduction in displacement when x topology and v topology outrigger are used on regular model is 6.67% when x topology is compared to v topology outrigger, thus x topology outrigger are more effective than v topology in regular model.
- The time period with x topology is reduced by 7.66% whereas with v topology it is reduced by 4.80% when compared to normal model.
- The increases in displacement can be seen when compared geometric irregularity with geometric+mass, geometric+stiffness and geometric+mass+stiffness, the percentage increases are 1.2%, 3.48% and 4.90 % for normal model.
- The reduction of displacement for all structure regular or irregular with mass, stiffness and geometric irregularity outrigger at half height gives good result as the percentage of displacement is reduced significantly compared to outrigger at different height.
- Outrigger have been increasingly used in buildings in recent decade. Due to their excellent lateral stiffness and aesthetic features, they have the potential to become a more widely- used structural system in high- rise buildings.
- As the lateral loads are resisted using outrigger with X and V Topology brace, the top storey displacement is less as compared to the normal building
- As time period is less, lesser is mass of structure and more is the stiffness, the time period is observed less in outrigger structure which reflects more stiffness of the structure and lesser mass of structure.
- The reduction in time period for all the models regular and irregular is more for outrigger at 20^{th} level as time period inversely related to its stiffness the reduction is 40% compared to normal model.

V. SCOPE OF FURTHER STUDY

- Further research can be carried out by considering the effect of wind loads on irregular shaped structures and also by considering the impact effects due to the blast loading on structure. Further research can be carried by using the same system with soil interaction properties.

REFERENCE

[1] Felipe Morrone Barbat Parfitt (2023), Multi-objective optimization of outriggers in high-rise buildings subjected to wind loads. IBRACON Estrut. Mater., vol. 16, no. 2, e16203,2023| https://doi.org/10.1590/S1983-41952023000200003

[2] Abdollahzadeh, G. (2023). Proposal of the Location and Shape of the Outrigger Arm and Belt Truss in the High Rise Buildings with the Central Core. *Numerical Methods in Civil Engineering,* .

[3] Alaa Habrah a, M. B. (2022). An analytical optimization study on the core-outrigger system for efficient design of tall buildings under static lateral loads. *sciencedirect*.

[4] Arsalan Alavi a, E. M. (2021). Uniform deformation design of outrigger braced skyscrapers: A simplified method for the preliminary design stage. *sciencedirect*.

[5] Ashtari, S. F.-T. (13 May 2020). Simultaneous size and topology optimization of 3D outrigger-braced tall buildings with inclined belt truss using genetic algorithm. *John Wiley & Sons, Ltd*.

[6] Chang, W.-S. &. (2018). Use of shape memory alloy in construction: a critical review. *Civil Engineering Proceedings of the Institution of Civil Engineers*.

[7] Chuangjie Fang, B. F. (2019). Optimization of damped outrigger systems subject to stochastic excitation. *sciencedirect.*

[8] Dhanaraj M. Patil, K. K. (2016). Seismic Behaviour of Outrigger Braced Systems in High Rise 2-D Steel Buildings. *sciencedirect*.

[9] Dhanaraj M. Patil, K. K. (2016). Seismic Behaviour of Outrigger Braced Systems in High Rise 2-D Steel Buildings. *sciencedirect*.

[10] Hamid Beiraghi, N. S. (2016). Seismic assessment of RC core-wall building capable of three plastic hinges with outrigger. *Wiley Online Library*.

[11] Han-Soo Kim, H.-L. L.-J. (2019). Multi-objective optimization of dual-purpose outriggers in tall buildings to reduce lateral displacement and differential axial shortening. *sciencedirect*.

[12] Hi Sun Choi, G. H. (2015). Outrigger Design for High-Rise Buildings. *taylorfrancis*.

[13] Huang, B., & Takeuchi, T. (2017). Dynamic Response Evaluation of Damped-Outrigger Systems with Various Heights. *Earthquake Spectra (2017).*

[14] Hyo Seon Park a, E. L. (2016). Genetic-algorithm-based minimum weight design of an outrigger system for high-rise buildings. *sciencedirect*.
[15] M. Samadi, N. J. (2019). Determining the effective level of outrigger in preventing collapse of tall buildings by IDA with an alternative damage measure. *sciencedirect*.
[16] Moon, K. S. (2016). Outrigger Systems for Structural Design of Complex-Shaped Tall Buildings. *International Journal of High-Rise Buildings*.
[17] Patel, P. (2021). Comparative Analysis of Wall Belt Systems, Shear Core Outrigger Systems and Truss Belt Systems on Residential Apartment. *International Journal of Research Publication and Reviews*.